No. X.

An Inquiry into the Causes why the Metals in a Solid State appear to be Specifically lighter than they are in the State of Fusion. By Joseph Cloud.—Read July 15th, 1814.

AN opinion has universally prevailed among chemists and metallurgists, that cast iron, in the state of fusion, occupies less volume, and is consequently denser, than it is in the solid state. This inference has arisen out of what has been considered an anomalous circumstance, that unfused iron will float on the surface of that metal in the fluid state. This, however, is not peculiar to iron; for, although it may have escaped the notice of others, experience authorises me to assert, that the same law appears to govern the other metals, under the same circumstances. This singular fact would naturally lead to such a conclusion; for, what better evidence can be looked for, in the laws of gravity, to establish the superior density of a fluid, than that of supporting the solid on its surface? but this paradoxical phenomenon appears to be irreconcileable with the laws of expansion and fusion.—Caloric, whose particles mutually repel each other, and the attraction of cohesion, are antagonist forces; the action of one always opposing resistance to, and diminishing that of the other. Expansion arises from the excess of energy, in the repulsive power of the caloric, over the force of cohesion, inherent in the ultimate integrals of the metal; and thereby increasing the distance, and diminishing the attraction of cohesion between them, until they are in a situation to move independently of each other; and thus constitute fusion. At this period, however, the attraction of cohesion is not completely destroyed; as an increased temperature and expansion are required to produce evaporation. To prove that the energy of attraction is not destroyed:—1st. If we place a small quantity of metal, in the state of fusion, on a plane surface, it will assume the spherical form; and, if two of these globules are made to approach, they will attract each other, and form one sphere. 2d. If a glass plate be laid on a globule of mercury, the globule, notwithstanding the pressure applied to it, endeavours to preserve its spherical form; if we gradually charge the plate with weights, the globule will be depressed and become thinner and thinner; but if we again remove the weights from the plate, the mercury will instantly recover its former figure, and push up the glass before it. From these facts it appears, 1st. That the metals, in a state of fusion, are not mere inert fluids, as they could not assume the globular form unless a real reciprocal attraction among their particles existed. The 2d proves that the attraction is not only superior to gravitation, but that it also overcomes an external force.

It is a practical fact, well known to every iron founder, that, in order to procure a casting of certain dimensions, it is necessary to have patterns and moulds, from 1-8th to 3-16ths of an inch to the foot, larger than the casting is intended to be; and that spherical castings, such as cannon balls, will be 1-66th of their diameter less than the moulds in which they were cast. The reverse of this would take place if it were true that iron, in the state of fluidity, occupied less space than the solid metal: for the fluid, when first cast into the mould, must necessarily fill its whole cavity; and its expansion in cooling would produce a casting of larger size than the pattern and mould.

The sharpness of iron castings has also been advanced as an evidence in support of the superior density of the fused metal. This circumstance, however, appears more probably to depend upon the fusibility of the metals; iron being the most infusible of the metals used for that purpose, it will necessarily produce the sharpest castings. For, when melted iron is poured into a mould, it runs like other fluids into all the interstices of the mould, which being at a lower temperature than that of the metal, the heat is conducted off from the external particles of the metal, by the first impression, and the surface is reduced to a state of solidity under the pressure of the superincumbent fluid before any change of temperature or contraction takes place in the centre;* in this way a shell of solid metal will be formed corresponding to the most minute impressions or figures of the mould, and although a subsequent contraction of the whole mass takes place, and the figures on the casting are diminished in size, they lose nothing of their sharpness and perfection.

Having briefly noticed the laws of expansion and fusion, and a few practical facts connected with iron founding, in which I flatter myself that I have satisfactorily shown the prevailing opinion respecting the superior density of the fused metal to be, if not erroneous, at least very doubtful, I shall now endeavour to account for the buoyancy of the unfused metals, from the laws governing the metals in the state of fusion. 1st. The attraction of cohesion existing among the particles of the fused metals. 2d. The radiant caloric escaping in a strong ascending current from all parts of the melted mass, its levity naturally giving it that tendency, and from its meeting least resistance in that direction. These co-operating powers will oppose the gravitation of the unfused metal, with a force sufficient to overcome its superior density, and support it on the surface of the fluid till it has nearly acquired the same temperature. This effect will necessarily be the most remarkably produced in the case of iron, in consequence of the intense degree of heat required to fuse it. The truth of this

* As the cooling process continues to go on from the surface to the centre, and the loss of temperature increases the attraction of cohesion, the particles of the metal will be drawn from the centre toward the surface; hence we find the centre to be hollow, or honeycomb, unless this effect is prevented by what the founders call a *sinking head*.

hypothesis is rendered more probable by the remarkable circumstance (noticed by Mr. Mushet) that the solid metal, notwithstanding its expansion by the increased temperature, sinks in the fluid when it arrives nearly at the fusing point, and previous to its passing into that state. This singular fact, however inconsistent it may appear, is, nevertheless, reconcileable with the laws of cohesion, repulsion, and gravity. The metals, in a state of fusion, do not operate as mere conductors of heat, but their particles, being considerably separated, like all other fluids, permit the caloric to pass in an uninterrupted current between them, without being subjected to the tardy and progressive conducting powers of the solid metal. The heat thus passing through the fluid metal, with increased facility, and striking the under surface of the unfused metal, will become subjected to the conducting powers thereof, and consequently be retarded in its progress: a strong current of ascending caloric will then continue to oppose the superior gravity of the unfused metal, and keep it buoyant until it arrives nearly at the melting heat, when it becomes so much expanded that the caloric is not entirely subjected to the conducting power of the metal; for, in proportion to the increased expansion, so will the passage of the caloric be facilitated, and its action on the unfused metal diminished until it ceases to oppose a sufficient force, co-operating with the attraction of cohesion, to prevent the unfused metal from sinking by its superior density.*

* Or, assuming what is no doubt generally the case, that the bottom part of a melting-pot is hotter than the upper part, and especially when a piece of solid, and comparatively cold, metal, is placed on the surface, a current in the particles of the melted metal will, on hydrostatic principles, take place, from the bottom upwards; and thus, from their mechanical impetus, will contribute to prevent the unfused metal from sinking. From a similar cause, if in a vessel of boiling water, a solid body of somewhat superior specific gravity, be laid on the surface, it will not sink, but remain buoyant, as long as the water boils.